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54 **A noise elimination method.**

57 The invention relates to a method for the elimination of noise in an information channel. The frequency band of the channel (1) is first divided (CH1-CH4) into sub-bands (B1-B4), whereafter the useful value of the signal of each sub-band (B) is determined by comparing the signal level (S) to a reference level (Ref), in which case a constant signal of substantially the same level as the reference level (Ref) is suppressed (P1-P4), whereas a varying signal, defined as a useful signal, is summated, unsuppressed, with the useful signals of the other sub-bands (B1-B4). The frequency band of the channel is divided into sub-bands (CH1-CH4) by means of an all-pass filter construction. The method can be implemented using an analog or a digital filter construction.

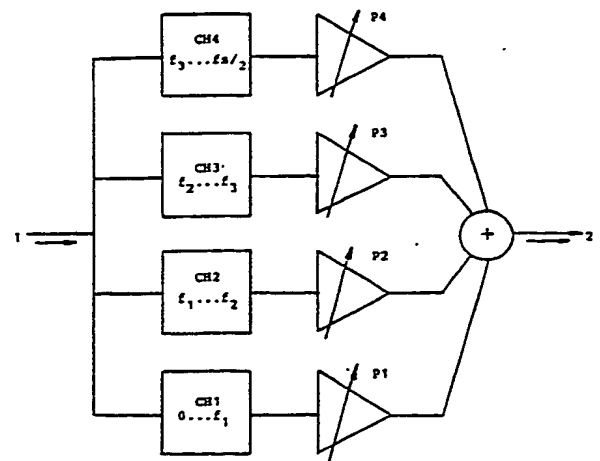


FIG. 1

A noise elimination method

The invention relates to a method for eliminating noise in an information channel by filtering a noisy signal coming through the channel.

Disturbing noise often appears in an information channel, specifically a communications channel, such as a mobile radio telephone channel. The noise may be due both to the connection and to noise around the actual source, the speaker. For example, the background noise in an automobile is heard as noise in the background of a telephone call spoken over a mobile radio telephone.

To eliminate disturbances and noise it is possible to use a plurality of methods. For example, by means of a high-pass filter it is possible to eliminate noise at low frequencies. However, in a signal coming to a mobile telephone from stations, the noise is within the same frequency range as is the speech signal, and so a situation is arrived at in which speech is also eliminated if attempts are made to eliminate the noise.

Endeavors have been made to eliminate the effects of background noise, when speaking from automobiles, by using, for example, a second microphone. Only noise is received in this microphone placed elsewhere in the automobile, and this noise can be eliminated from the entire signal before the speech signal is transmitted further from the telephone. Only slight improvement of the signal to noise ratio has been achieved by this method, since suitable placing of the microphone is difficult.

The object of the present invention is to eliminate the problems appearing in the methods described above and to provide a method by which it is possible to eliminate noise in an information channel without suppressing the speech signal.

According to the invention the problem presented is solved by first dividing the frequency band of the channel into sub-bands, whereby the noisy information is divided into sub-signals, and by thereafter separately determining the useful value of the signal of each sub-band by comparing the signal level to a reference level, in which case a signal substantially of the reference level is defined as noise and is suppressed, whereas a varying signal, defined as a useful signal, is summated, substantially unsuppressed, with the useful signals of the other sub-bands in order to form filtered outgoing information.

Frequency bands containing nothing but noise or a great deal of background noise can in this case be eliminated. This is possible, since a speech signal does not use the entire frequency range all the time.

The invention is described below with the help

of an embodiment example, with reference to the accompanying drawing, in which

Figure 1 is a block diagram of the principle of an arrangement with which the method according to the invention is implemented;

Figure 2 is the construction of a four-channel filter bank;

Figure 3 depicts a filter pair consisting of a low-pass filter and a high-pass filter;

Figure 4 is a block diagram of an arrangement with which the suppression of a single channel is controlled;

Figure 5 illustrates the division of a frequency band into sub-bands;

Figure 6 is a characteristic curve determining the amount of signal passage.

The principle of the implementation of the method is depicted in Figure 1 as a block diagram. A signal 1 is supplied to the filter blocks CH1-CH4, in which the signal is divided into frequency bands B1-B4 (Figure 5). The outputs of the filters are coupled to suppressors P1-P4, by means of which it is possible to eliminate frequency bands which contain nothing but noise. Finally the bands are again summated, and the improved signal 2 is carried further.

The division into frequency bands B1, B2, B3 and Bn is implemented using the all-pass filter construction according to Figure 2. The limit frequencies of the frequency bands are f_1, f_2, f_3 .

The transfer function of the all-pass filter of the first stage is

$$A_1 = (a + z^{-1}) / (1 + az^{-1})$$

and respectively the transfer function of the all-pass filter of the second stage is

$$A_2 = (b + cz^{-1} + z^{-2}) / (1 + cz^{-1} + bz^{-2})$$

where coefficients a, b and c are obtained from the formulae

$$a = \sin(\omega/2 - \pi/4) / \sin(\omega/2 + \pi/4)$$

$$b = (a^2 + \alpha) / (1 + \alpha a^2)$$

$$c = (2a(1 + \alpha)) / (1 + \alpha a^2)$$

where $\omega = 2\pi f/f_s$ and $\alpha = f_s/4f_H$

and f_H = limit frequency of filter

and f_s = sample taking frequency of filter

The filters of the first and second stages have been formed into low-pass - high-pass pairs (Figure 3) by means of which the signal is always divided into two frequency bands. Three filter stages are required in order that a division into four frequency bands will occur.

The suppression control depicted in Figure 4 is carried out in each frequency band by setting the amplification of the signal according to the following equation

$$p = \max \{(S-2N)/S, C\}$$

where S = signal level

N = noise level

C = constant indicating the maximum suppression of the bands, in practice, for example 0.2.

If there is no signal within the frequency band being examined, the signal level S and the noise level N are approximately equal, and the passing amount of the frequency band is C. If the signal S is substantially greater than the noise level N, the passing amount P attains a value and the signal is not suppressed at all.

The monitoring of the signal level is carried out by rectifying (10) and low-pass filtering (11, 12) the signal of the frequency band.

The low-pass filter 11 can be, for example, the recursive filter of the first stage

$$Y_s(k) = A_s Y_s(k-1) + (1-A_s) X_s(k)$$

where $A_s(k)$ = coefficient

$Y_s(k)$ = output signal

$X_s(k)$ = input signal

The noise level N within each frequency band is detected by further low-pass filtering (12) the signal coming from the level detector and by detecting (13) from this the long-term minimum. Thus it is possible to determine whether the frequency band in question has a constant-value signal (which is noise) or a signal of continually changing value, which can be deemed to be a useful signal. The recursive filter of the first stage may again serve as the low-pass filter

$$Y_n(k) = A_n Y_n(k-1) + (1-A_n) X_n(k)$$

where the terms stand for the same as in the previous formula. Referring to Figure 4, $X_n(k) = Y_s(k)$.

The minimum is calculated from the equation

$$N(k) = \min \{Y_n(k), N(k-1) + \delta\}$$

where δ = constant representing the maximum increase rate of the noise level N.

Four was chosen as the number of frequency bands in the examples. An increase in their number increases the number of all-pass blocks (quadratically). From the viewpoint of practical implementation, it is hardly worth while increasing the number of bands. In the present application, 3 is a good choice for the number of frequency bands.

The functioning of the method has been verified by practical subjective experiments.

It is evident that the method can be applied using different circuitries. Both analog and digital circuit constructions are usable.

Claims

1. A method for the elimination of noise in an information channel by filtering the noisy signal coming through the channel, so that the frequency

band of the channel (1) is first divided (CH1-CH4) into sub-bands (B1-B4), whereby the noisy information is divided into signals, characterized in that thereafter the useful value of the signal of each sub-band (B) is determined by comparing the signal level (S) to a reference level (Ref), in which case a signal substantially of the same level as the reference level (Ref) is defined as noise and is suppressed (P1-P4), whereas a varying signal, defined as a useful signal, is summated, substantially unsuppressed, with the useful signals of the other sub-bands (B1-B4) in order to form filtered outgoing information (2).

2. A method according to Claim 1, **characterized** in that, when the signal level (S), detected on a sub-band, exceeds the reference level (Ref), its passage is increased in inverse proportion to the amount of the excess in accordance with a given characteristic curve (Figure 6), in which case the signal levels exceeding the determined upper limit (Max) are substantially not at all suppressed.

3. A method according to Claim 1, **characterized** in that the signal level (S) to be compared is formed by rectifying (10) and low-pass filtering (11) the signal, and that the long-term minimum (N) is formed as the reference level (Ref), in which case the amount of signal passage (P) at any given time is obtained from the formula:

$$P = \max \{(S-2N)/S, C\}$$

where S is the signal level, N is the noise level, and C is a constant indicating the minimum gain of the sub-band.

4. A method according to any of the above claims, **characterized** in that the frequency band of the channel is divided into sub-bands (B1-B4) by using an all-pass filter construction (Figure 2).

5. A method according to any of the above claims, the information channel being a base-frequency speech channel of a communications channel, **characterized** in that the frequency band of the channel is divided into four sub-bands (B1-B4).

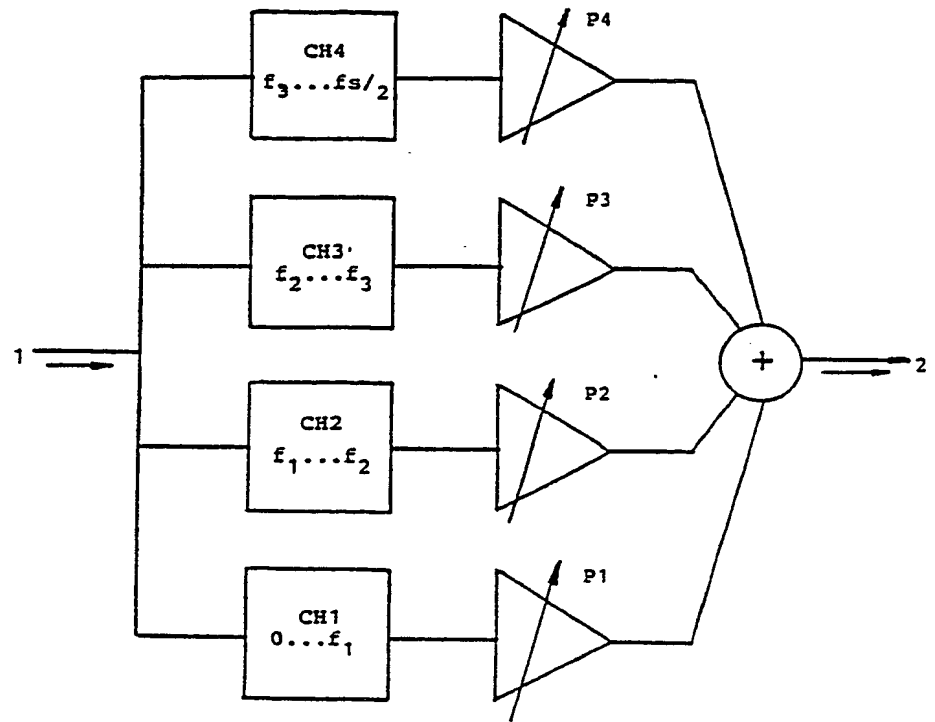


FIG. 1

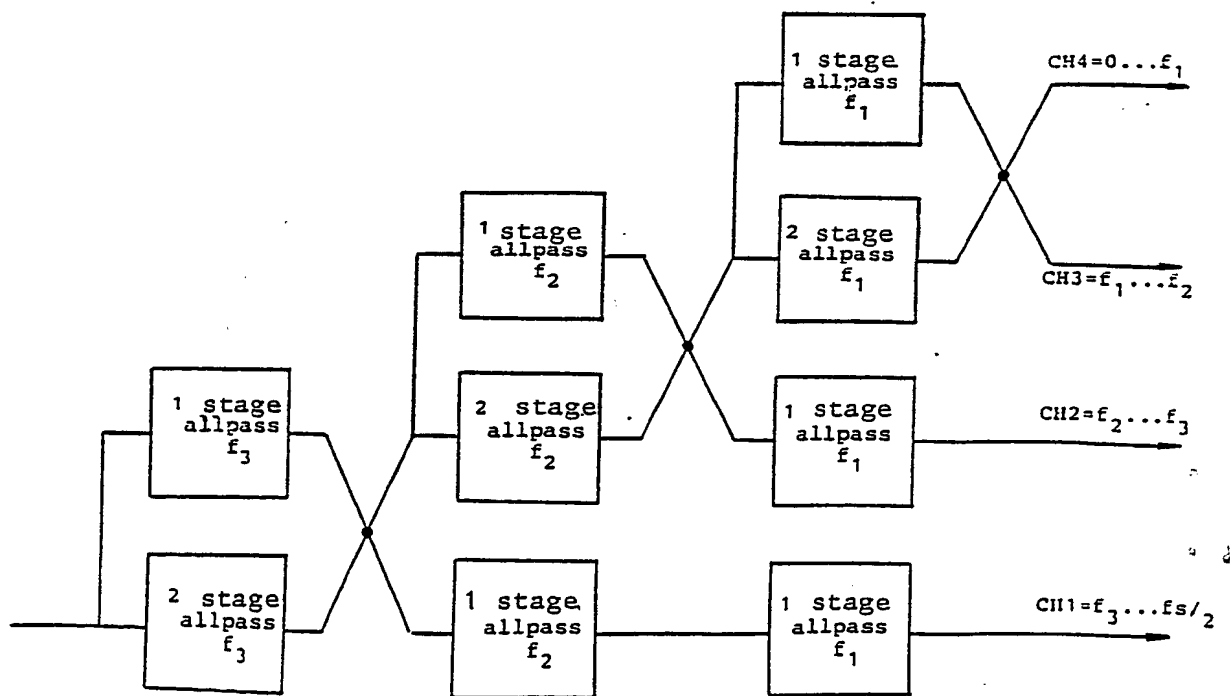


FIG. 2

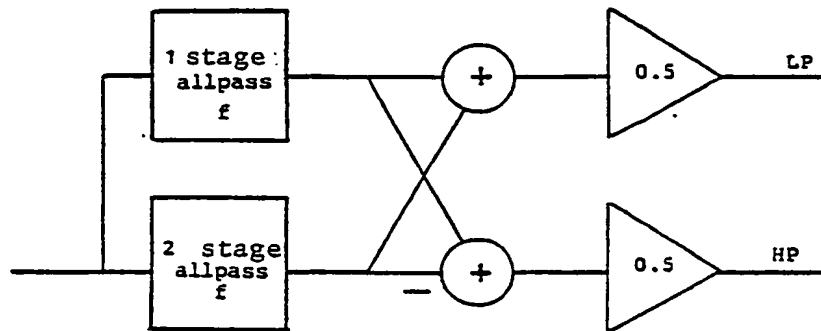


FIG. 3

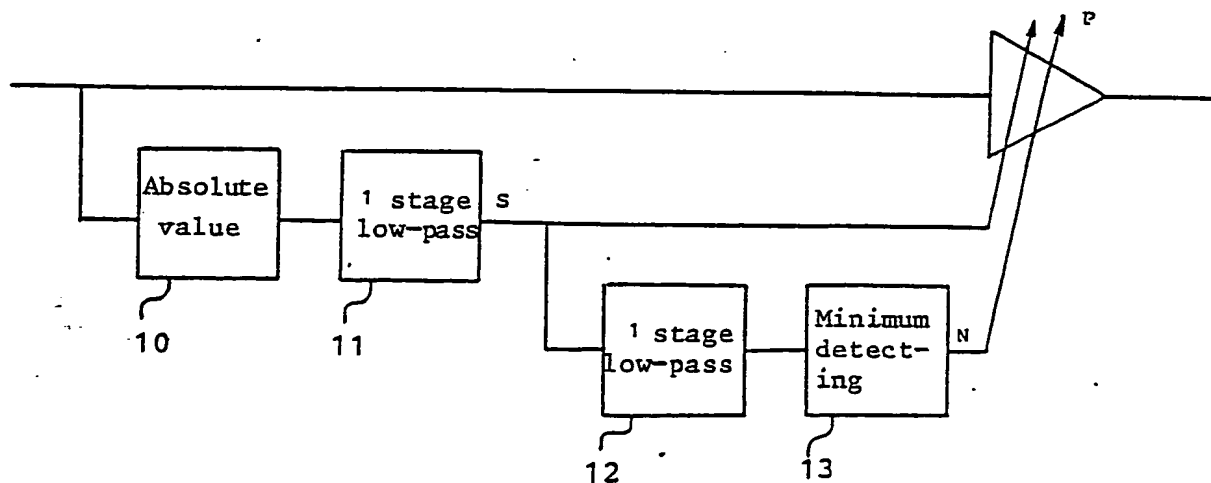


FIG. 4

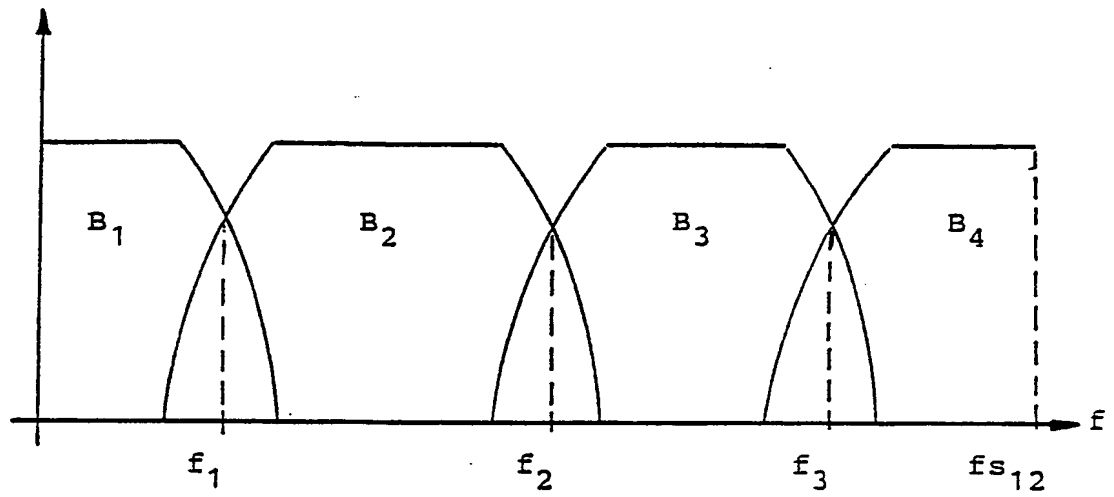


FIG. 5

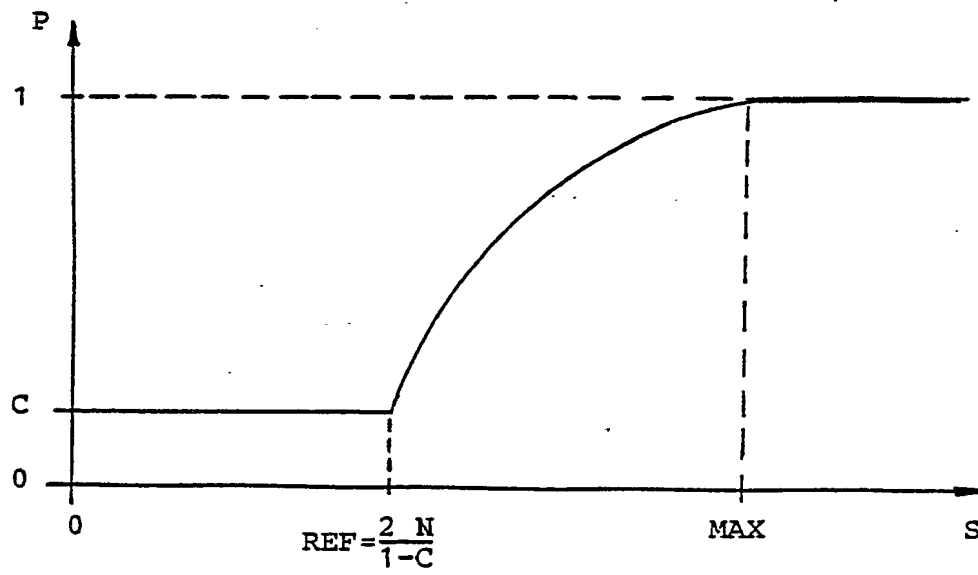


FIG. 6

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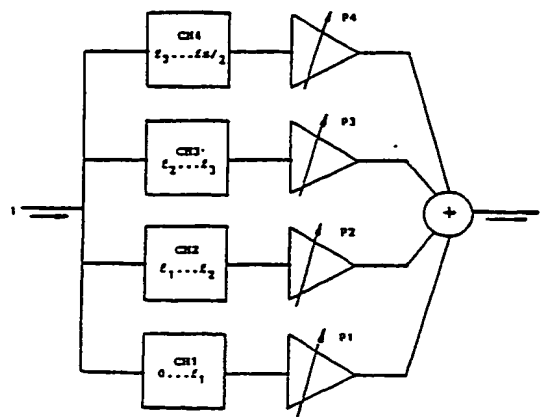


FIG. 1



DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	IEEE INTERNATIONAL CONFERENCE ON ACOUSTICS, SPEECH AND SIGNAL PROCESSING, ICASSP'82, Paris, 3rd - 5th May 1982, vol. 1, pages 168-171, IEEE, New York, US; G. DOBLINGER: "'Optimum" filter for speech enhancement using integrated digital signal processors" * Page 168, right-hand column, line 7 - page 169, left-hand column, line 21; page 169, left-hand column, line 45 - right-hand column, line 16; page 169, right-hand column, lines 53-78; figures 1-2 *	1-2	H 03 H 17/02 G 10 L 3/02
Y	IDEM	3	
A	IDEM	5	
X	THE BELL SYSTEM TECHNICAL JOURNAL, vol. 60, no. 8, October 1981, pages 1847-1859, American Telephone & Telegraph Co., New York, US; M.M. SONDHI et al.: "Improving the quality of a noisy speech signal" * Page 1848, line 1 - page 1849, line 5; page 1849, line 40 - page 1850, line 14; page 1850, line 36 - page 1851, line 12; page 1853, lines 10-16; page 1854, lines 10-21; figures 1-2, 5a *	1	
Y	IDEM	3	
A	IDEM	2	
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 20-07-1990	Examiner WRIGHT J.P.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- & : member of the same patent family, corresponding document	



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X	IEEE INTERNATIONAL CONFERENCE ON ACOUSTICS, SPEECH, AND SIGNAL PROCESSING, ICASSP'84, San Diego, CA, 19th - 21st March 1984, vol. 1, pages 12B.1.-12B.1.4, IEEE, New York, US; D. PELLONI et al.: "Enhancement of audio based on digital techniques" * Page 12B.1.1, left-hand column, lines 1-17; page 12B.1.1, right-hand column, line 35 - page 12B.1.2, left-hand column, line 19; page 12B.1.2, left-hand column, line 53 - right-hand column, line 6; page 12B.1.3, lines 4-42; figures 1,3 *	1, 4	
A	IDEM -----	2	
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 20-07-1990	Examiner WRIGHT J.P.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- & : member of the same patent family, corresponding document	

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